HOPI CORN PRODUCTION

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Leigh,

We are providing all participants with a copy of the study report. Several copies have been sent to the Tribe through official channels. Thank you for your ~~??~~ participation as an individual farmer, and as director of the Tribe's cultural program.

Thomas M. Davis
BIA - Phx Area Office

TABLE OF CONTENTS

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LIST OF FIGURES

LIST OF TABLES

ABSTRACT This study of Hopi corn yields is placed within the context of Hopi physical, social, and cultural resources and the activities of the annual agricultural cycle. Interviews with thirty-two farmers and the corn sampled from thirty-four fields in nine locations on the Reservation provided the data required to conduct the study. Yields were highest with: smaller fields located in areas receiving flood waters; fields planted with at least ten seeds per hill by a digging stick at a depth of at least 8"; and in fields with excellent weed control. Although a complete understanding of yield requires the collection of data under a range of climate conditions, these preliminary results stand as testimony to the knowledge and practices described for traditional Hopi corn farming.

INTRODUCTION

Hopi agriculture developed around the production of open pollinated corn. It is an intensively managed farm system long studied and admired by natural and social scientists alike. Scholars look at the Reservation's relatively poor soils, difficult climate conditions, and its lack of irrigable water, and they marvel at the ability of the Hopi people to develop and use the water and soil conservation techniques necessary to produce sustainable crop production. Social scientists have been intrigued with the relationships between farming and the whole of Hopi culture, with particular interest in its history, religion, and social organization.

Given the importance of corn to Hopi farming and Hopi culture in general, it is interesting that no previous study has focused on production or yield. The initial impetus for this study was a desire to determine corn yields for the range of field conditions found on the Reservation. Yield data, however, are only meaningful when viewed within the context of the production system as a whole over time. Ideally, a study of agricultural production would include participant observation with farmers during all phases of the annual cycle under the range of possible weather conditions. The research reported on here constitutes a beginning in this endeavor.

This report gives an introduction to Hopi corn farming, and it provides baseline data on yield in an abnormally dry year. The study design is presented, followed by an introduction to the physical, social, and cultural resources with which farmers work. The activities of the annual cycle of agricultural activities are then given. This background gives the necessary context for understanding the results of the yield study. The report concludes with farmer input on perceived problems and suggestions for future research.

STUDY DESIGN

The guiding factor in designing this study was the documentation of yield in dryland corn production. The selection of fields and farmers to study was based on an effort to include all human and environmental factors that might affect yield throughout the Reservation.

An obvious starting place with respect to environmental factors is the consideration of field type and location. Information on field type relates to physiographic location, soils, and access to water. Soil type played a particularly important role this year because fields with a large percentage of clay in the topsoil simply did not produce a crop.

Other factors potentially affecting yield relate to individual farmer characteristics. Farmers vary with respect to goals, knowledge, skills, interests, resources, and actual farming practices. Some farmers, for example, are acknowledged to have a "green thumb." I presented the following list to a Hopi farmer before initiating the study to determine if variation exists within the community and who might represent this variation: age of farmer; location of domicile; equipment inventory; varieties planted; planting dates; crop rotation practices; water and soil conservation practices; fertilizer practices; and pest control practices. Planting practices, for example, are one area where variation exists and can readily be identified. Does planting with a digging stick versus planting with a corn planter affect yield? Or, what effect does the timing of planting have on yield?

Forty fields were examined. In five cases, no corn was sampled. In four of these cases, the field produced very little or no corn. In the fifth case, the farmer did not want any corn removed. As can been seen on the map in Figure 1, the fields are located in nine sections across the Reservation.

I attempted to interview all the farmers whose fields were sampled. A Hopi translator was present at all times. Of the thirty-two farmers with fields sampled, twenty-six were formally interviewed (See Appendix A for the interview format). An additional six farmers were interviewed, bringing the number formally interviewed to thirty-two.

The formal interview was essential to obtain the information necessary to present the annual cycle. Interviews were generally one-half to one hour long, although more in-depth interviews and follow-up discussions were done with six farmers. I also interviewed nine farmers in their fields, affording more specific information on farming practices.

The interview did not request the farmer's age, but it is estimated that eight or 25% of the farmers formally interviewed are under fifty years of age. No farmer was younger than twenty years old.

HOPI PHYSICAL, SOCIAL, AND CULTURAL RESOURCES

Any study of farming should include an inventory of the resources with which people work. An introduction to the physical resources of Hopi agriculture sets the stage for what is possible, it gives the parameters or working conditions farmers must take into account. The social and cultural resources of a group of people are equally important in understanding a farming system. It is people who farm, people who select and mold their physical resources to produce their basic necessities. Nature proposes, man disposes.

Physical Resources

This introduction to the physical resources of Hopi farmers begins with the geography of the Reservation. Climate information follows, with a comparison of precipitation data for 1994 with averages for the past thirty years. This section concludes with general information on field types and soils.

Hopi occupies the south central portion of the Colorado Plateau in Northern Arizona. Current boundaries of the Reservation surround the southern escarpment of Black Mesa.

> The northern part of the reservation consists of high, steep-sided mesas and plateaus separated by wide valleys and deeply entrenched southwest-flowing ephemeral drainages. The Cretaceous Mancos shale and Mesa Verde group make up the slopes and escarpments of the mesas and underlie moderately deep to deep eolian and alluvial deposits on the mesa tops. The contact between these geologic formations forms an aquifer that feeds small springs along the mesa edges. Elevations in the highlands range from 5,800 to 7,100 feet (Prevost et al. 1984:170).

Four mesas run southwest from Black Mesa: Antelope; First Mesa; Second Mesa; and Third Mesa. These Mesas are separated by four washes which contain the bulk of farm fields on the Reservation: Polacco, Wepo, Oraibi, and Dinnebito. Most of the farm fields are also in relative proximity to Route 264, which crosses the Reservation just south of these four mesas.

The climatic conditions of Hopi are demanding. The growing season is within a range of 144-170 days where most farming takes place (Adams 1979). The last spring frost normally occurs in mid-May, and the first killing frost comes as early as late

September. Rainfall can vary considerably from year to year. Average rainfall for the past thirty years is 6.77" in Tuba City, 10.84" in Keams Canyon, and 11.74" in Ganado, AZ (National Oceanic & Atmospheric Administration 1995). April, May, and June, the driest months, are accompanied by strong winds that can be very hard on young plants. The rains of July and August can bring violent thunderstorms. The only area with access to irrigation, Moenkopi, was not included in this study.

In 1994, precipitation figures ranged from 36-57% below normal. Keams Canyon, for example, received 4.68" instead of the average 10.84". As can be noted in Table 1, Keams Canyon was particularly dry in July and August, critical months in determining the success of the corn crop (Ibid). The elevation range for the fields sampled is 5,420' to 4,900', with an average elevation of 5,690'.

TABLE 1. HOPI PRECIPITATION DATA

	Tuba City 4,940'Elevation	Keams Canyon 6,205'Elevation	Ganado 6,340'Elevation
30 Year Av.	6.77"	10.84"	11.74"
1994	4.30	4.68	6.77
July/Aug. 30 Yr. Av.	1.68	2.99	3.46
July/Aug. 1994	.92	.63	.77

In 1942, Hack listed four main classes of Hopi fields based on four means of water supply. These main classes contained thirteen types of fields. The most common type over time has been the ak-chin field, a field made on the fan of a tributary water course. Bradfield's characterization of the attributes of this field type (1971:34) promote an understanding of why it has enabled sustainable production:

(a) it receives the run-off from an area of rock ledge and talus slope;
(b) it has a covering of fine sand, some 4 to 6 inches deep, which acts as a mulch and prevents evaporation of moisture from the subsoil;
(c) the subsoil itself contains enough clay to give it a fairly high moisture-retaining capacity.

Prevost et al. (1984:170) built on Hack's classification scheme, but only found four field types remaining:

fields are located on small alluvial fans at the mouths of intermittent tributary streams, which water spreads out naturally after storms; on low stream terraces adjacent to drainages that flood during major storms; on sand dunes that receive only rainfall and limited underground seepage; and on artificial terraces constructed near springs to use all available water.

The first type represents the traditional ak-chin field described by Bradfield (1971).

The fields included in this study represent two field types: the traditional ak-chin type fields, and a second type which will be referred to as an open field watered solely by rainfall. This type is not mentioned in Prevost et al and it was not common historically. Prevost acknowledged the presence of this type and referred to it as a "modern" field (Personal communication 1994).

Hopi fields have generally been located on three kinds of soils: "soils that are sandy in the upper part and loamy in the lower part, soils that are loamy throughout, and soils that are sandy throughout" (Prevost et al 1984:171). Fields watered by surface runoff contain alluvial soils. These soils are either a clay type apt to be alkalinic or they are typically well-drained sandy soils. Farmers talked about the soil in the ak-chin fields as "flood" or tsibok'vasa soils.

The soils found in the fields sampled are classified as: loamy upland 2, sandy upland 2, sandy loam upland, sandy loam, silty loam, silty upland 2, clay fan, and sandy terrace. Not all fields have been classified due to religious reasons (Soil Conservation Service 1983).

Social Resources

Social resources are the people and social arrangements available to support farming. Access to land and labor are key social resources of farming systems.

Access to fields has traditionally been associated with the Hopi matrilineal system (Forde 1963). Fields have been collectively "owned" or considered to be in the custody of clans. Each clan disbursed its land as it saw fit to both male and female members. Since clans typically had land in more than one area, people frequently had fields in multiple locations. This arrangement helped insure yields since it increased the chance that at least one field would receive sufficient moisture to produce a crop.

The traditional clan system of land ownership is more intact at some villages than at others today. In some villages, more land is individually held than clan held. Many new fields are also being developed next to government housing.

The Hopi male performs the bulk of the labor necessary to farm today. Men are proud to provide corn for their family, and they enjoy being in their fields. One farmer said that the "only place I'm happy" is in the fields. Another described farming as in his heart. A third remarked that he has a passion for farming. A fourth farmer commented on the desirability of farming in order to partake in the frequent farming discussions in such social settings as the kivas.

Men want their wives to take an interest in their farming, and they appreciate their support and the proper care of the harvest. Some farmers believe that if a wife makes negative comments about her husband's farming, it can affect his yield.

Farming is an important part of Hopi identity, and there are many interested males with the necessary knowledge and skills of farming. The farmers interviewed did not cite a labor shortage, but they did express dissatisfaction that they personally could not devote more hours to their fields. Farming is something Hopis like to do and choose to do. This may not be as true for Hopi youth. Some Tribal elders think today's youth have been negatively impacted by the dominating culture and have come to shun physical labor.

A farmer's equipment inventory strongly influences his labor arrangements. Ten farmers or 31% of those interviewed do not own a tractor, even though the presence of tractors on the Reservation dates to the early 1950's (Bradfield 1971). The tractor is nonetheless considered indispensable for field preparation. Farmers will borrow equipment or pay someone to plow, disc, or cultivate their fields. Among the farmers interviewed, six borrow equipment, another six pay to have someone else do fieldwork, and one rents equipment. The "going rate" for custom work is $30/hour, although some reportedly pay from $20 to $50/hour. Farmers in Hotevilla have the option of renting community-owned equipment for a fee of $15/hour.

Villagers, clansmen, relatives, and friends used to get together at a prearranged date to plant or harvest each other's fields. With the availability of modern equipment and other changes in Hopi lifestyle, communal labor parties are no longer practiced by everyone. One of the farmers interviewed has chosen to continue this tradition. To him, this is an important part of Hopi corn farming and the maintenance of social relationships.

Cultural Resources

Cultural resources can be defined as the traditional knowledge, beliefs, and skills that have been accumulated over generations among Hopi farmers. Traditional knowledge regarding Hopi corn farming must include a broad scope because of ties to Hopi religion. Farming is considered a religious activity, and raising corn is believed to be very sacred. "You put your stick in Mother Earth and a child is born." Many farmers think of corn as their children, and they treat it in a manner considered appropriate for children: tend to it daily; touch it; sing to it; pray for it; be kind to it; talk to it; and generally care for its every need. In many ways, one's corn crop is symbolic of an individual's goodness or how he behaves in a religious sense.

Additional insight into Hopi beliefs regarding farming is afforded in Don Talayesva's autobiography (Simmons, ed. 1942), which conveys the advice Mr. Talayesva received from his uncles and fathers when he inquired about making a living in Hopi.

> Corn is our mother--the main support of our lives--and only the Cloud People can send rain to make it grow. Put your trust in them. They come from the six directions to examine our hearts. If we are good, they gather above us in cotton masks and white robes and drop rain to quench our thirst and nourish our plants. Rain is what we need most, and when the gods see fit they can pour it on us. Keep bad thoughts behind you and face the rising sun with a cheerful spirit, as did our ancestors in the days of plenty. Then rain fell on all the land; but in these evil days it falls only on the fields of the faithful. Work hard, keep the ceremonies, live peaceably, and unite your heart with ours so that our messages will reach the Cloud People. Then maybe they will pity us and drop the rains on our fields.

This quote echoes what some Tribal elders consider to be the "secret" to successful corn farming. It is considered hard work, but it is also "what's in your mind" and "what's in your heart." One farmer simply advocated to, "Take your religion seriously."

An introduction to the Hopi lexical inventory for corn also helps convey the importance corn has in Hopi culture (See Note 1). The general term for an ear of corn is timat, literally translated as an offspring of the stalk or mother, a little baby wrapped up. The ear is referred to as pivikyawya when the kernels are immature and all white. When the corn has matured to a sweet, milky stage with colored kernels, it is called sami or fresh, green corn. With fully matured, dry kernels, the ear is referred to as qaaö. Humita is shelled corn or the kernels. Kernels literally mean life to the Hopi. When kernels are used for planting, they are called poshumi or seeds. A Hopi farmer plants seeds for life. Barren stalks, qatungwu, are symbolic of the spirit and essence of one's body. They also represent the parents of the corn. Once the ears or children are harvested or taken home, the parents are ready to go back to earth, their life cycle complete. See also Figure 2.

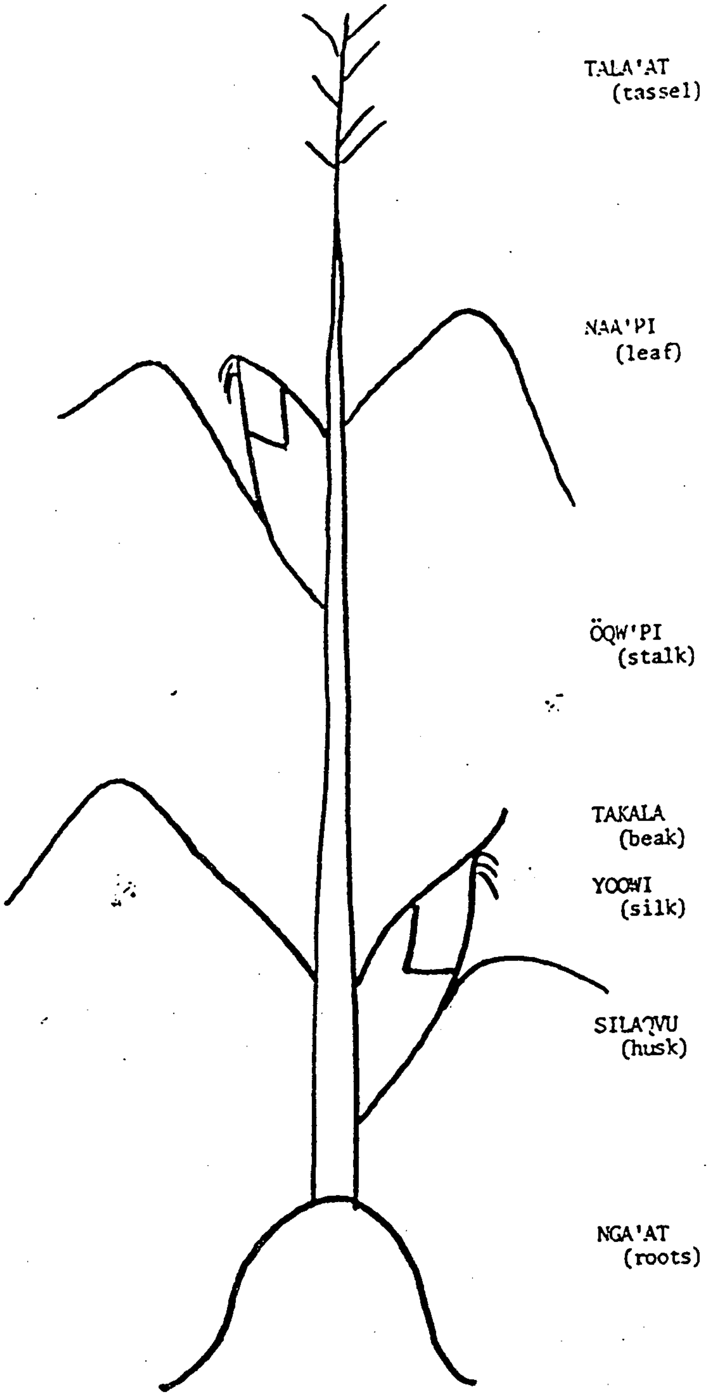

FIGURE 2. HOPI TERMINOLOGY FOR CORN

The traditional method of planting with a digging stick is symbolic of the Hopi conceptualization of life and the life plan that exists for everything (Leigh Jenkins, personal communication 1995). The Hopi farmer marks each end of the rows and then runs up and down the rows to mark the plan for the field, showing where to plant the seeds and promoting the growth of these seeds. The stages of growth in corn are symbolic of a person's stages of growth, each to be nurtured and cherished.

Corn is valued as a source of food and it is used "symbolically at every turn" in ceremonial activities throughout the year (Forde 1963:243). Corn is also viewed as a person's riches. A person who has corn is considered culturally rich. One farmer mentioned that corn is better than money in the bank. Another noted that you can never have too much corn. One grandfather prophesied to "Keep planting. You never know what is going to happen." For the majority of his life, one man has only lived off what he produced. Because corn is so fundamental to Hopi life, people prefer to keep at least a one year supply on hand.

THE ANNUAL CYCLE OF HOPI CORN FARMING

The annual cycle of corn production begins with the preparation of the field for planting and ends with the harvesting of the crop. Care must be taken with each operation to secure a crop.

Field Inventory

In the formal interview, thirty-one farmers gave an inventory of their corn fields. As noted earlier, Hopi farmers historically had more than one field in multiple locations. This acted as a kind of crop insurance. Today most farmers (55% of those interviewed) still have more than one field, but these fields are usually tangential to each other. In other words, a single block of land is divided up into two or three fields. The most common division is for one section or field to be in blue corn and the other to be in white corn. Even though seventeen farmers have multiple corn fields (See Table 2), only six farmers have these fields in different locations. This change may reflect the constraints on time farmers experience today. This is especially true for younger men do not farm for a living. It is also very expensive to drive farm equipment back and forth between fields.

Field Preparation

For the vast majority of Hopi farmers, field preparation begins in the fall. Only one of the farmers interviewed does not plow or disc in his corn stalks after harvest. This farmer has

TABLE 2. INVENTORY OF CORN FIELDS

NUMBER OF CORN FIELDS FARMED	NUMBER FARMERS
1	14
2	8
3	6
4	2
5	1

his soil preparation custom-done, and this may help explain why he does not work with his soil in the fall.

Fall plowing or discing is done primarily to promote the retention of winter moisture. One farmer may deep plow to 15" to accomplish this. Another variant is to disc over a plowed field after the first snow but before the ground freezes.

Only two farmers were noted to graze livestock on their fields before working the stalks into the soil. If the soil has a relatively high percentage of clay in it, it is believed that animals can compact it, significantly reducing the amount of winter moisture absorbed. Two farmers also noted that once livestock learn where feed is, they seek to return to it. This would be disastrous for farmers without fences.

Most farmers disc the field springtime before planting. Farmers will also plow springtime if the ground is hard. Some farmers also drag a weight over the field or harrow it at the first sign of warmth to seal off any cracks and form a crust to protect against the loss of soil and moisture due to winds.

Farmers who plant with a digging stick want minimal soil disturbance in the spring. Their primary reason for fieldwork prior to planting is to promote weed control. Cultivating with a sweep or blade may suffice. If not, these farmers will also disc their fields.

Planting

Planting is accomplished with a tractor-drawn corn planter or the traditional digging or planting stick. Fourteen farmers or 44% of those interviewed do not own a corn planter. Twelve of these farmers do all their planting with a digging stick. Some farmers with corn planters prefer to plant their "early corn" with a digging stick. People choose to plant with a digging stick because they believe: they can plant the seed deeper; it promotes root growth because the stick is inserted past the desired planting depth; there is less rodent damage; it looks better; and it is important for maintaining a cultural tradition of group planting. Only one farmer practices group corn planting.

Hopi farmers are very skilled at solving their farming equipment needs. The digging sticks observed were made of metal and manufactured on the Reservation. A second example is the design and manufacture of a suitable corn planter. Four of the farmers interviewed have designed and made their own planters. Some of these designs require someone to feed the planter during planting, others are more automated. Farmers enjoyed describing their planters, and for the most part, they are pleased with their operation.

The timing of planting requires more research to fully describe. Calendar dates are one way to convey timing. Other factors mentioned include: waiting until a particular clan plants; considering the exact position of the sun, moon and stars from one's village; and waiting until the blackbirds come.

Twelve farmers reported planting "early corn," a small portion of their total planting, in early spring. Early corn is not a particular variety, but rather reflects the timing of planting. No particular variety was mentioned to be superior for planting at this time. One farmer said that everyone wants to be the first to plant so he will be the first to have fresh corn on the table. Most of this early corn is planted in April in order for it to be sufficiently mature for the village's Home Dance, which is usually in July. There is also a preference for the Kachinas to help harvest fresh corn to bring into the villages then.

The majority of the corn crop is planted in May, with some farmers planting until the end of June. One farmer planted in early July this year even though this is considered too late to expect the corn to fully mature. Another farmer practices succession planting from mid-April to early June. Many farmers replant due to worm damage with the seed or young plants.

Planting is done with generous spacing between rows and between plants within the rows. A common spacing is four steps separating the hills. New rows are made inbetween last year's rows. Even with plowing, farmers reported that they can still tell where last year's rows are.

Planting depth can be discussed in terms of a measure or the presence of soil moisture. Farmers prefer to place the seed in moist soil. The average planting depths given range from 4" for seven farmers to 12 or 13" deep for two farmers. Historically, the Hopis were observed to plant at least 12" deep with the digging stick (See Beaglehole 1937:40, Bradfield 1971:5, and Forde 1963:229). Deep planting helps insure that the seeds have adequate moisture for germination and it is believed to help protect the plants from floods and heavy rains.

The number of seeds placed per hill can be considerable. While the average number of seeds planted per hill in 1994 is 6-8, four farmers put as many as 20 seeds per hill. A large number of seeds, from 10-20 per hill, is the amount documented in the ethnographic literature (Ibid.). These seeds may have been soaked or placed in the farmer's mouth just prior to planting.

Today, a large number of seeds planted per hill in part reflects anticipated damage from worms. If worms have been a problem in the past, farmers figure some seeds will be consumed prior to germination or that some plants will die soon after germination. Farmers also think that a heavier seeding rate functions to protect young plants from heavy winds. Some farmers reported planting heavier for blue corn than for white corn. Farmers would rather plant too many seeds and thin than replant.

Variety Planted

Farmers were asked to identify Hopi corn varieties and to note the varieties they planted in 1994. Every farmer interviewed planted blue corn, and all but one farmer planted white corn.

Hopi corn varieties are identified by color or appearance. Each colored variety is associated with the cardinal directions, and each has a particular use in religious ceremonies. White corn, for example, is used in the child naming ceremony. The following varieties are the basic ones recognized (See Note 2):

Blue corn	<u>sakwapu</u>
White corn	<u>qöötsa</u>
Red corn	<u>palangpu</u>
Purple corn	<u>kokoma</u>
Purplish or lavender corn	<u>wiqwtö</u>
Yellow corn	<u>takuri</u>
Speckled or pinto corn	<u>avatsqaö</u>, <u>maasi</u> or <u>pinto</u>
Supai corn	<u>Koninqaö</u>
Mixed colors	<u>Nanayqaö</u>
Hopi sweet corn	<u>tawaktsi</u>
Hopi popcorn	<u>kököyaphoya</u>
Rio Grande corn	<u>Hopaqwqaö</u>
Commercial sweet corn	<u>pahantawaktsi</u>

The Supai corn is recognized as a fast maturing corn originating from the Havasupai Tribe in the Grande Canyon area. The Rio Grande corn is the Eastern white corn reported in Whiting (1939:67). Farmers describe it as a variety that produces a tall plant which needs more water and more time to mature than the traditional Hopi varieties.

Some Hopis recognize additional corn varieties. These varieties were initially identified by verbal descriptions rather than by sight. This proved to be confusing, especially when people could not provide Hopi names for the variety described. A Hopi woman assisted with this effort by attaching Hopi names to actual ears selected from her storage bins. In keeping with her frame of reference, these additional varieties are grouped according to the color flour they produce.

Corn producing blue flour:

1. Maasiqa'o or grayish blue kernels
   This variety was recognized by 7 farmers.
2. Saqwapuh
3. Kokoma
4. Pinto
5. Kwaqaö or eagle corn
   Eagle corn has white kernels with blue eagle designs on each kernel.
   Recognized by 1 farmer and acknowledged to be rare.

Corn producing white flour:

1. Wukoqötsaqaö or a white hominy-type with large, hard kernels.
2. Tsatsayqötsaqaö or white corn with smaller ear, smaller kernels.
   Recognized by 4 farmers.
3. Palatspipi or a red and white corn.
   Recognized by 3 farmers.
4. Palangpu
5. Koninqao

Corn producing yellow flour:

1. Takuri

Corn producing lavender flour:

1. Wiqwtö

Please note that varieties are considered distinct when they breed true, when the offspring characteristics are maintained consistently from generation to generation. See Whiting (1939) and Soleri and Cleveland (1993) for more discussion on Hopi crop varieties.

Seed Selection

Seed selection or the decision making process for saving seeds for next year's planting is based upon the criteria listed in Table 3. The largest number of responses (12) essentially indicate that any healthy kernels are satisfactory. This may relate to a cultural tradition that teaches Hopis not to place one thing above something else (Leigh Jenkins, personal communication 1994). Each kernel is believed to have honor and a spirit. Other criteria relate to the production characteristics of the kernels (big kernels, kernels that go to the tip of the ear, and four year old kernels) and the plant (small ears, smaller plant, and long ears). Four men stated that they do not participate in the selection process because this is their wife's job.

Although not given as a response during the formal interview, color is an important characteristic influencing seed selection. Farmers like to keep the colors pure. No one, however, mentioned attempts to prevent cross-pollination. One farmer thinks the effort to prevent cross-pollination would be futile with the strong winds present in Hopi.

A final factor influencing seed selection relates to religious practices. One farmer said that the seeds he receives from Mudheads at a winter ceremony are mixed with his home seeds to get a better crop.

TABLE 3. SEED SELECTION CRITERIA

CRITERIA	NUMBER RESPONDENTS
Healthy looking, mature kernels	12
Big kernels	4
Don't know, the women pick	4
Big ears	2
Small ears, big kernels	2
Smaller plant, big kernels	1
Long ear, big kernels	1
Kernels to the tip of the ear	1
Four year old kernels	1

Experimentation with the different corn varieties was a subject of conversation with only two farmers. This was unexpected and in contrast with what Whiting found in an earlier study when he noted that Hopi farmers are "keen to note differences in the quality, season, or other desirable characters, and seed corn is often selected with these factors in mind" (Whiting 1939:12). Two farmers expressed an interest in improving Hopi sweet corn. One of these farmers felt that a relative disinterest in corn breeding may be due to the perception that Hopi corn has reached a plateau performance-wise. In other words, it is already the best that it can be.

Thinning/Weeding

As the seeds germinate and grow, farmers survey their fields to determine if thinning is necessary. Farmers generally prefer 3-8 stalks per hill. One farmer leaves 8 stalks if it has been a windy spring, 4 stalks if the wind was subdued. One farmer mentioned that he likes to thin out the middle stalks, leaving a circle of stalks. Another type of thinning mentioned by one farmer is to remove the side shoots that did not produce ears before tasseling and silking. He thinks this practice enables the plant to save water for better kernel production.

Weeding is taken seriously by the Hopi farmer. A clean field leaves more moisture for the plants, and farmers believe that it helps keep the worm populations down. Farmers also think that a clean field reflects the kind of job they are doing with their corn.

Farmers generally weed by machine between the row and by hand between the plants. The tools used to weed include: tractor-drawn sweeps, a blade or disc, a hoe, and a hand-powered cultivator. Three farmers have also tried a chemical herbicide, and they have been very pleased with the results. One wondered about the possibility of his soil becoming addicted to herbicides if repeated applications are used.

The timing of weed control is dependent upon the weather. It usually begins in June, and may be done three times a season. Some farmers like to weed daily, and it shows. This past year some farmers only cultivated the field once because there was so little weed growth due to limited rainfall.

Irrigation

Farmers were asked if they brought any moisture to their fields. They either said no or they smiled and replied that they dance a lot or pray for rain all the time.

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Soil Fertility

The vast majority of corn produced in the U.S. is done with the aid of chemical or organic fertilizers. Only three Hopi farmers mentioned applying any kind of fertility agent: a commercial soil conditioner every now and then; ashes once-in-awhile; and one farmer tried commercial fertility sticks with each hill once to little or no effect.

Field location and soil preparation practices are seen as ways to naturally enrich soil. Three farmers stated that their fields are in a wash area that receives rich sand on a somewhat regular basis. Four farmers believe that discing in the stalks after harvest increases soil fertility. Farmers are also aware that a rotation to beans and allowing the field to lie fallow are other ways to enhance soil fertility.

Soil fertility is not much of an issue because the soil is believed to support satisfactory crop production year after year in most locations. Soil is not viewed as a limiting factor, rain is. Twelve fields in this study, for example, have been in continuous corn production for over sixteen years. Many of these fields have been in continuous corn for so long that people do not remember exactly how long.

Soil Conservation

Soil conservation is believed to be more difficult to practice today with larger fields and more mechanized agriculture. Soil preparation practices were the most commonly mentioned conservation measures (9 farmers). Blading instead of plowing and discing in an east-west manner are two examples of practices that are believed to save soil. Such windbreaks as tires and cans around plants and shrubs around a field are also believed to help stop wind erosion. No one referred to such early practices as the construction of brushwood fences, earthen banks, or stone walls to control wind erosion (Beaglehole 1937).

Pest Control

In October, pests were on everyone's minds as the evidence of crow damage in particular was overwhelming. In some cases, as many as two dozen crows, really ravens (<u>Corvus corus</u>) but called crows by everyone, flew into the air as we approached a field. It was astonishing how the crows literally harvested most of the corn in some fields. The crow population forced many farmers to harvest earlier than normal this year. It was considered better to harvest the corn a bit green than to leave it for the crows.

The control measures tried for crows included: shooting; hanging dead crows in the field; placing continuous music in the field; hanging a wide assortment of noisy, colorful things that fly in the wind; constructing scarecrows; hiring someone to guard the field; putting timed bombs in the field; camping overnight near the field; and wrapping ears with newspaper. These measures might be effective for a short term, but the Hopis think that their crows are smart. People think it is important to be in the field continuously when the corn is almost mature because that is when the crows prefer to come. "As soon as I leave, they come back." Only one person seemed satisfied with his crow control program, which consisted of many large garbage bags hung throughout the field. He believes the secret to success here is the daily maintenance of the bags. Other birds such as jays and meadowlarks can also be a problem.

Some farmers were under the impression that crows are a protected species today and that it is illegal to shoot them without special permission. Research with Arizona Fish & Wildlife revealed that crows are not a protected species. Crows are a migratory bird, but they are not threatened or endangered.

Some farmers want and need help controlling crows. In the meantime, the Hopi sense of humor comes to the rescue. Farmers say that the radios in the field, for example, are really placed there to entertain the crows while they eat. Crows also need music for their dancing. The bombs set off in the field are carefully timed so the crows can set their watches. The aluminum plates, tins, and colorful rags flying in the wind are in truth the plates and napkins needed for civilized dining. Mirrors are positioned so the crows can powder their noses. The Hopi farmer does his best to make his "guests" feel comfortable and at home.

Rabbits, gophers, prairie dogs, and rats are another group of pests that are believed to seriously affect the Hopi corn field. The control measures used for these animals are: spraying dog manure on plants; putting dried rabbit intestines and water around the plants; applying poison; shooting on sight; setting traps; spraying pine sol for rabbits; filling prairie dog holes daily; and putting butane and diesel in prairie dog homes. Only the last two measures were considered satisfactory in controlling prairie dogs.

The third type of pest affecting corn is the worm population. Worms are a problem at planting time and again when the ear is beginning to mature. Sometimes farmers put cans around hills at planting to discourage the worms from finding the seeds. When seeds fail to germinate or farmers see yellow plants, they dig into the soil for the worms. This needs to be done for each hill in the field. This may be effective some years, but when there are 20-30 worms per hill, it is considered a losing battle. Better to replant than to try to kill all those worms. Nothing is done to control the damage from worms found mostly on the tip of the ear in the fall.

Other types of worm control measures include fallowing a field and burning stalks. One farmer thinks that leaving a field in fallow for 1-2 years helps control worms. Another farmer will burn his stalks to promote worm control.

Animals, birds, and insects have always been part of the natural environment, but they may not always have been considered a problem to the Hopi farmer. Traditionally farming was the Hopi farmer's life and he went to his fields daily. Some people think that birds and animals are more apt to be viewed as pests today because farmers do not devote as much time to the care of their fields. Some would say that it is not the animals that are the problem, rather it is the change in the Hopi lifestyle.

Harvest

All Hopi corn is harvested by hand. No one has harvesting equipment, and no one mentioned the need for any.

It is believed that most Hopi farmers begin harvesting once the corn is mature enough to eat green, which can be as early as July. There is a period of about one week when the kernels on a particular ear are in a sweet, milky stage. This stage can occur at different times for each ear, and it can last up to a month for the entire field. Into the research it became apparent that people regularly pick corn once it reaches this state of maturity. The Hopis like to eat this green corn and they value sharing it with friends and family. Some farmers estimated harvesting as much as half of their crop during this green stage.

A number of roasting pits, a kind of underground oven, were observed next to fields. Farmers say they still enjoy roasting ears over coals in an earthen pit. Roasting occurs primarily with green corn. Beaglehole (1937:44) describes the process whereby sweet corn was roasted in these pits in the 1930's.

Farmers began their final harvest this year in early October, just prior to the first killing frost, because of a vigorous crow population. Normally, farmers wait until after this frost because both the plant and the kernels are drier, making picking easier and the final drying process faster. One farmer also mentioned that this frost kills worms and that the corn seems to dry harder and preserve better. Some farmers do not commence with their mature corn harvest until after a particular women's society ceremony, which occurred in late October this year.

Traditionally corn was harvested by groups of people. It was a social event and a work party as people harvested each other's fields. One farmer considers this an important tradition to continue. He announces his harvest date in his village, and the following day people come help. Helpers are fed and they may receive part of the crop if his wife determines that the yield exceeds her needs.

Once the harvest has been completed, some farmers go over the field to be sure each ear was removed because each kernel is considered important. Other farmers choose to leave a few ears for nature.

Corn is laid outside to fully dry down. Corn was observed drying on roof tops, assorted boards, and on special wire racks with covers. Roasted sweet corn is sometimes strung together and hung outside near the entrance to the house.

Completely dry ears are stored in metal garbage-type containers with lids or in specially made wooden boxes. All the homes visited had storage containers with corn in them. Usually a single variety is stored per container.

The Hopis have a cultural tradition of sharing their harvest that is still practiced. One farmer reported that it is considered acceptable for someone to harvest part of another's crop if he leaves the husks there so the farmer knows corn was removed. Another farmer pointed out the belief that the more corn one gives, the more blessings there will be in return. It is believed to be important to always save and share corn.

Some farmers will sell or trade corn with each other and with outsiders. Five farmers mentioned that the going price in 1994 is $25 for a twenty-five pound flour sack of shelled corn. Hopi farmers are well known for their corn production in the region, and people travel to Hopi specifically to buy Hopi corn.

YIELD STUDY

This section describes the procedures used to estimate corn yields on the Hopi Reservation in 1994. It then gives the results of the yield study and considers factors that might help explain differences in yield.

Methods

The following procedure was used for collecting samples in all fields. At least one assistant and myself walked to the middle of the field, attempting to assess uniformity of production. We took samples on the diagonal of the field that appeared most representative of yield for the entire field. If one corner of the field was barren and the rest of the field was not, for example, that corner was not sampled.

All the ears present in a ten foot area constituted a sample. The number of samples taken was based on an estimate of field size. If field size was estimated to be .1 to 3 acres, four samples were taken. If the field was 3.1 to 10 acres in size, six samples were taken (Iowa Crop Improvement Association, Personal communication 1994). From the field center, a set number of paces were counted off in an effort to reach most of the diagonal of the field.

Other measurements taken in each field include: row and plant spacing; an assessment of weed control; and a determination of the field's soil and topography. A sketch of the field was made so the field can be resampled in future years in roughly the same places.

Yield numbers were obtained from the corn sampled in thirty-four of the forty fields shown in Figure 1. Corn was sampled in an additional field, but the yield from this field was abnormally high, 86% higher than the highest yield for the rest of the group, due to a sampling bias. When we arrived at this field, the farmer had harvested all but a few rows so corn was sampled from only a single row.

Each sample was placed in a paper bag for transport from the field, and then placed outside the bag in a room for drying. The number of ears per sample and a notation of pest damage per ear was recorded for each sample. Once the ears were dry--no bending of the cob and the kernels "crackled" with handling--the corn was shelled and weighed for each sample.

The following formula was followed to derive a yield figure for each field:

1. The average row spacing was divided by 12 to get a linear feet number.
2. The linear feet figure was multiplied by 10 to get square feet per acre.
3. The number of square feet is divided by the total number of feet per acre to get the area sampled or C.
4. The weights of each sample were averaged to determine the average yield for the entire field.
5. C is multiplied by the field's average yield to calculate average pounds per acre for the field.

This formula was obtained from George Dickerson, the New Mexico State University State Horticultural Specialist for Cooperative Extension. It was used in similar research on corn production in Zuni, New Mexico (Manolescu 1994).

Results

Yields ranged from 2.4 lbs/ac. to 522.7 lbs./ac. The average yield for the group is 173.5 lbs./ac. According to Dickerson (personal communication 1994), unfertilized fields of open pollinated corn can be expected to yield 1,000 lbs. per ac. at best.

Twelve factors were considered for their influence in explaining variation in yield: location, field size, topography, variety, date planted, technology used for planting, depth of planting, number of seeds planted per hill, row spacing, plant spacing within the row, weed control, and the production loss from pests in Sample C. The figures for these factors are given in Table 4.

The fields sampled for yield data are located in nine different units across the Reservation: Shongopovi, Unit 256, Unit 257, North Oraibi, South Oraibi, Hardrock, Polacco Wash, Toreva, and East Dinnebito. Thirteen fields or 38% are located in North Oraibi. The ranking of yield averages from these units are given in Table 5. Five of the six highest producing fields are located in North Oraibi, with the sixth field located in East Dinnebito. All locations experienced yields under 200 lbs./ac.

TABLE 4. YIELD AVERAGES PER FIELD LOCATION

FIELD LOCATION	NUMBER CASES	YIELD AVERAGE IN POUNDS PER ACRE
South Oraibi	1	14.7
Unit 257	1	81.5
Polacca Wash	5	92.7
Unit 256	2	131.1
Hardrock	3	155.8
Shongopovi	2	172
Toreva	3	175
East Dinnebito	4	186
North Oraibi	13	230.5

Field size consisted of two categories: fields estimated to be less than acs. and fields estimated to be from 3 acs. to less than 10 acs. Twenty-seven fields fell into the less than 3 ac. category, with seven fields 3 acs. or more. The average yield for the smaller fields is 191.2 lbs./ac, and the average yield for the larger fields is 105 lbs./ac. The smaller fields are represented by the lowest and the highest yielding fields for the group.

TABLE 5. RESULTS OF THE HOPI YIELD STUDY OF 1994

ID	LOC	SIZE	TOPO	VAR	DATE	TECH	DEPTH	HILL	ROW	PLANT	WEED	LOSS	YIELD
23.000	400.000	1.000	2.000	2.000	52.000	2.000	4.000	14.000	8.110	8.900	1.000	888.000	2.440
35.000	700.000	1.000	2.000	1.000	42.000	2.000	7.000	7.000	8.110	9.010	1.000	83.000	14.700
10.000	200.000	1.000	2.000	1.000	999.000	1.000	999.000	999.000	5.110	7.000	2.000	888.000	22.100
7.000	200.000	2.000	2.000	1.000	999.000	1.000	7.000	6.000	7.100	5.100	3.000	888.000	27.800
22.000	400.000	1.000	2.000	2.000	62.000	1.000	6.000	8.000	8.110	10.100	1.000	888.000	29.300
11.000	300.000	1.000	1.000	1.000	42.000	1.000	5.000	7.000	7.100	7.900	1.000	75.000	33.400
33.000	200.000	1.000	2.000	3.000	61.000	2.000	999.000	999.000	11.500	10.800	3.000	20.000	45.800
39.000	400.000	1.000	2.000	2.000	999.000	1.000	999.000	999.000	9.800	9.800	1.000	80.000	63.100
6.000	200.000	2.000	2.000	1.000	999.000	1.000	7.000	6.000	7.700	6.010	3.000	50.000	74.700
3.000	257.000	2.000	2.000	1.000	52.000	1.000	5.000	6.000	9.010	7.100	2.000	888.000	81.500
36.000	600.000	2.000	2.000	1.000	53.000	2.000	9.000	19.000	11.900	14.400	3.000	888.000	81.600
40.000	600.000	1.000	2.000	2.000	999.000	999.000	999.000	999.000	10.700	12.010	1.000	33.000	90.600
2.000	256.000	2.000	1.000	1.000	53.000	1.000	7.000	19.000	10.200	16.700	1.000	888.000	102.300
21.000	200.000	1.000	2.000	2.000	51.000	2.000	7.000	5.000	6.800	6.800	1.000	98.000	111.200
26.000	200.000	1.000	1.000	1.000	52.000	2.000	5.000	8.000	8.400	8.100	1.000	25.000	130.700
38.000	400.000	1.000	2.000	1.000	999.000	1.000	999.000	999.000	9.800	8.900	1.000	27.000	130.800
4.000	100.000	1.000	2.000	3.000	51.000	1.000	10.000	12.000	8.300	7.000	1.000	36.000	132.000
13.000	300.000	1.000	1.000	1.000	53.000	1.000	12.000	7.000	7.900	9.400	2.000	83.000	134.900
20.000	500.000	1.000	2.000	3.000	52.000	1.000	9.000	8.000	8.000	3.900	1.000	28.000	157.900
1.000	256.000	2.000	1.000	2.000	53.000	1.000	7.000	19.000	10.800	22.000	1.000	90.000	159.300
19.000	500.000	1.000	1.000	999.000	52.000	1.000	7.000	8.000	6.110	8.800	1.000	56.000	176.500
16.000	500.000	1.000	2.000	1.000	999.000	999.000	999.000	999.000	7.100	10.600	1.000	888.000	190.700
27.000	200.000	2.000	1.000	2.000	52.000	2.000	999.000	7.000	8.700	8.110	1.000	12.000	208.200
5.000	100.000	1.000	2.000	2.000	51.000	1.000	10.000	12.000	7.700	7.800	1.000	30.000	212.600
31.000	600.000	1.000	2.000	2.000	62.000	2.000	10.000	8.000	9.010	10.300	1.000	888.000	230.300
15.000	400.000	1.000	2.000	2.000	61.000	1.000	5.000	7.000	9.400	9.800	2.000	888.000	238.100
34.000	200.000	1.000	2.000	3.000	61.000	2.000	999.000	999.000	9.700	6.110	3.000	15.000	268.300
12.000	300.000	1.000	1.000	1.000	999.000	999.000	999.000	999.000	10.600	9.110	1.000	10.000	299.100
28.000	200.000	1.000	2.000	3.000	333.000	1.000	10.000	7.000	9.600	10.010	1.000	13.000	330.100
32.000	600.000	1.000	2.000	2.000	51.000	2.000	8.000	7.000	10.010	8.800	1.000	6.000	341.400
8.000	200.000	1.000	1.000	2.000	999.000	2.000	9.000	10.000	8.400	9.200	1.000	888.000	350.400
24.000	200.000	1.000	1.000	1.000	52.000	2.000	13.000	20.000	7.800	7.110	1.000	23.000	426.500
9.000	200.000	1.000	1.000	3.000	999.000	2.000	9.000	10.000	9.600	8.800	1.000	9.000	476.900
25.000	200.000	1.000	1.000	2.000	52.000	2.000	13.000	20.000	8.900	5.700	1.000	28.000	522.700

Location: 100-Shongopovi; 200-N. Oraibi; 300-Hardrock; 400-Polacca; 500-Toreva; 600-E. Dinnebito; 700-S. Oraibi
Size: 1=-3 acs, 2=3+ acs.; Topo: 1=flood; 2=open; Variety: 1=blue; 2=white; 3= mixed; Date: 333=succession; 4's=April; 5's=May; 6's=June; Tech: 1=planter; 2=stick; Depth is in inches; Hill: # seeds per hill; Row: Spacing in feet; Plant: Spacing in feet; Weed: 1=excellent; 2=good; 3=fair; Loss: Given in percents; Yield: Lbs./Ac.
999=Don't Know; 888=Not Available

One would expect topography to be a predictor of variability in Hopi yields. The flooded fields should receive more moisture than fields located in flat, open areas that only receive direct rainfall. Twelve fields (35%) were classified as flood fields, with twenty-two fields (65%) considered open fields. The flood fields averaged a yield of 251.8 lbs./ac. while the open fields averaged just 130.8 lbs./ac. For the twelve fields yielding less than 100 lbs./ac., eleven or 92% are in open fields. The four highest producing fields are flood fields.

Three varieties of corn are represented in the study: 14 fields with blue corn; 13 fields with white corn, and 6 fields with mixed varieties. All three varieties are represented in the highest and lowest producing fields. Average yield for blue corn was 125.1 lbs./ac, while white corn averaged 196.9 lbs./ac.

Two fields were planted in April, sixteen in May, five in June, and one field was planted over a period of time from February to June. The two fields planted in April had yields of 14.7 lbs/ac. and 33.4 lbs./ac. The fields planted in May yielded an average of 186.4 lbs. corn per ac., while the June plantings resulted in an average of 162.3 lbs./ac.

The trend in Hopi farming is to increasing the use of mechanical planters. In 1994, seventeen fields were planted with a corn planter and fourteen were planted with a digging stick. The planter resulted in an average yield of 123.9 lbs./ac. but the digging stick yielded an average of 229.4 lbs./ac.

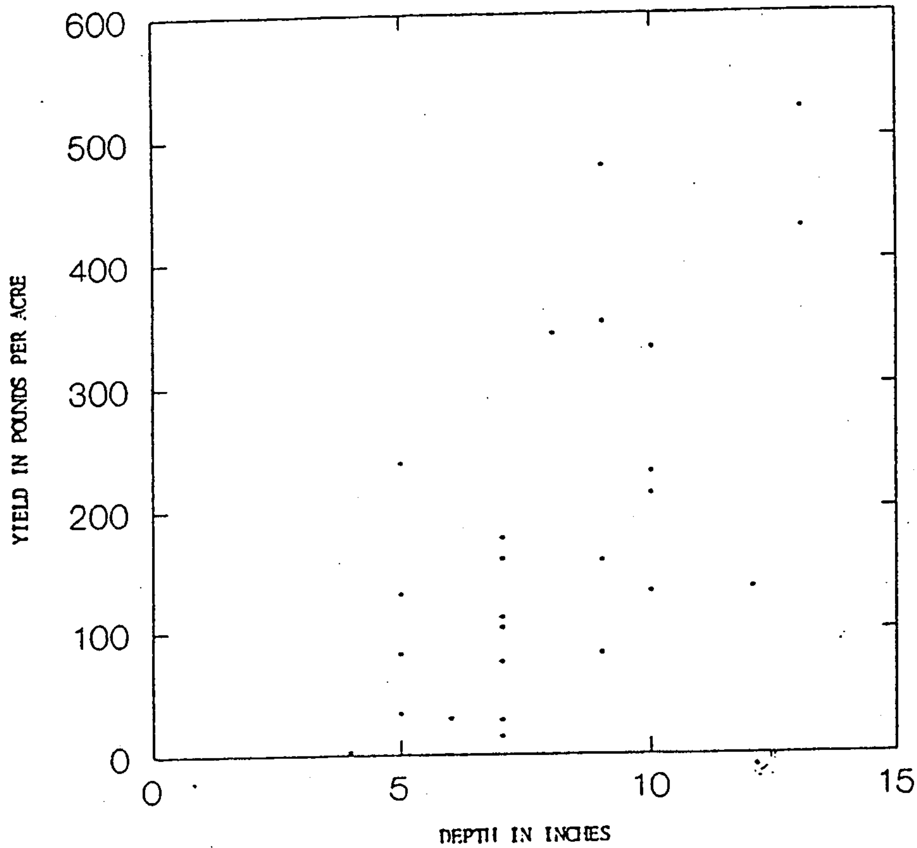
The relationship between planting depth and yield illustrates why Hopi farmers have historically planted their corn seed deep in the soil. Farmers reported planting from 4" to 13" deep in 1994. As can be noted in the scatter plot in Figure 3, the highest yields occurred when seeds were placed at least 8" deep. The average yield for farmers planting 8" deep or more was 293.1 lbs. ac., while those planting less than 8" deep only yielded 107.5 lbs/ac.

The number of seeds planted per hill varied from as few as five to as many as twenty seeds. The correlation between the number of seeds planted and yield averages is given in Table 6.

TABLE 6. CORRELATION BETWEEN SEEDS PLANTED PER HILL AND YIELD

NUMBER SEEDS/HILL	NUMBER CASES	YIELD AVERAGE IN POUNDS PER ACRE
5- 9	16	145
10-14	5	234.9
15-20	5	258.6

FIGURE 3. RELATIONSHIP BETWEEN YIELD AND PLANTING DEPTH



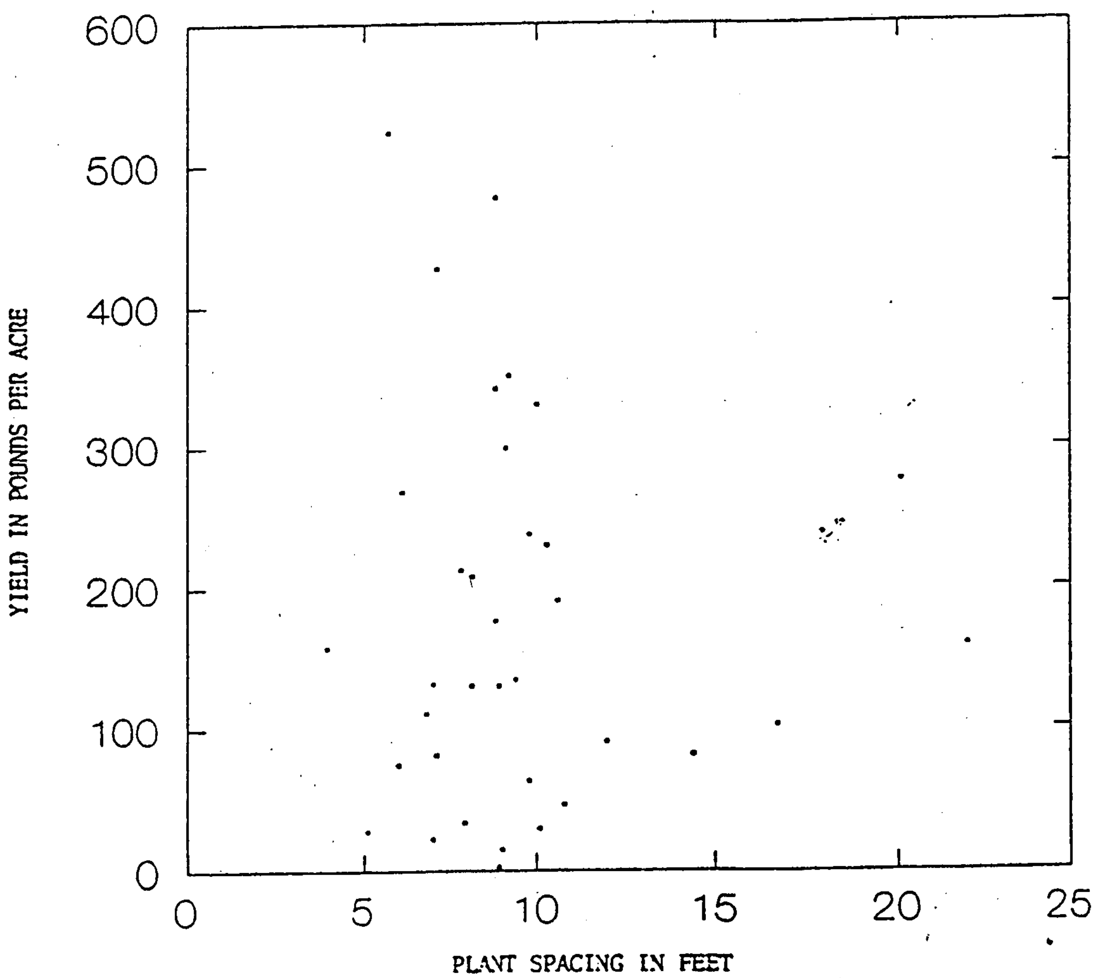
Row spacing measured from 5' to nearly 12 'in the fields studied. Both higher and lower yields were obtained with greater distances between the rows. The average yields with the different row spacings are included in Table 7.

TABLE 7. RELATIONSHIP BETWEEN AVERAGE YIELDS AND ROW SPACING

ROW SPACING IN FEET	NUMBER OF FIELDS	AVERAGE YIELD IN POUNDS PER ACRE
5	1	22.1
6	2	143.9
7	7	157.2
8	9	172.
9	8	227.4
10	5	198.6
11	2	63.7

Plant spacing within the row ranged from approximately 4' to 22'. The majority of fields were in the 7-10' range, with all yield variations found here (See Figure 4). Plant spacing beyond 10' did not result in higher yields.

FIGURE 4. RELATIONSHIP BETWEEN YIELD AND PLANT SPACING



Weed control was assessed to be excellent in twenty-five fields, good in four fields, and fair in five fields. No field exhibited poor weed control. All but two of the fields with an above average yield had excellent weed control. Six of the nine fields with good or fair weed control produced under 100 lbs./ac. See Table 8 for average yields for the different weed control ratings.

TABLE 8. RELATIONSHIP BETWEEN WEED CONTROL AND YIELD

WEED CONTROL	NUMBER OF CASES	AVERAGE YIELD IN POUNDS PER ACRE
Excellent	25	196.9
Good	4	119.2
Fair	5	99.6

A special effort was made to assess pest loss because pests are a major concern of farmers and because pest loss was believed to be relatively high in 1994. Also, in conversation it appeared that farmers may be underestimating yield loss due to the corn ear worm. Sample C, a sample collected from the center of each field, was examined for an estimated loss due to worms, animals, or crows. Loss was expressed as a percent of the kernels removed per ear due to pest, not a weight figure. No effort was made to determine the relative loss to the three categories of pests because it was not always apparent where the worm quit eating and the crow took over.

Pest loss estimates ranged from 6% to 98% of Sample C. All fields yielding above 200 lbs./ac. occurred with a pest loss from Sample C of 30% or less. Yield loss due to pest type occurred as follows:

Worm only	14 fields
Worm, Crow	6 "
Worm, Animal	2 "
Worm, Animal, Crow	2 "

The percent of loss in Sample C due to the corn ear worm alone ranged from 6-80%, with an average loss of 28%.

Discussion

These yield figures should be considered conservative because they do not take into account the green corn harvested from the field. Green corn harvesting was not a factor in an earlier yield study conducted with Zuni farming because Zuni farmers harvest very little green corn and they tend to pick it from one part of the field (Manolescu 1994). Preliminary discussions on Hopi farming did not uncover the extensive amount of green corn harvesting many farmers later mentioned. Because this situation was not known prior to the design of the research, it was not adequately probed. Six people were asked to estimate their green corn harvest, and their responses ranged from 5-50%, with an average of 30% of the crop believed to have been harvested prior to maturity.

A comparison of the various alternatives present in Hopi corn farming enables additional analysis of the yield data. To obtain a point of reference for the data given in Table 9, please recall that the range in yields per acre is 2.44 lbs. - 522.7 lbs, with 173.5 lbs. the average yield per acre.

TABLE 9. SUMMARY OF THE ANALYSIS OF YIELD STUDY RESULTS

VARIABLE	AVERAGE YIELD IN POUNDS PER ACRE	DIFFERENTIAL INCREASE
>3 Acres	105	
<3 Acres	191.2	82%
Open Field	130.8	
Flood Field	251.8	93%
Blue Corn	125.1	
White Corn	196.9	57%
Corn Planter	123.9	
Digging Stick	229.4	85%
Planting -8" Deep	107.5	
Planting 8"or Deeper	283.1	163%
June Planting	162.3	
May Planting	186.4	14.8%
5-9 Seeds	145	
10-14 Seeds	234.9	62%
15-20 Seeds	258.6	An additional 10%
Fair Weed Control	99.6	
Good Weed Control	119.2	20%
Excellent Weed Control	196.9	An additional 65%

In addition to the above figures, if fields were located in North Oraibi, Toreva, or East Dinnebito, yields were above average. Row spacing at 9′ and 10′ gave the highest yields, but no meaningful conclusions can be drawn from the yield correlations with plant spacing.

If one looks at any particular field in Table 5, the above results generally hold true. The highest yielding field, #25, for example, is located in North Oraibi. It is less than 3 acs. in size, and it is a flood field of white corn planted with a digging stick. Planting was 13" deep with twenty seeds per hill. Weed control was excellent.

Given that moisture is considered to be the limiting factor in Hopi corn farming, the relative picture that most of the data give make sense. In other words, one would expect more moisture to be available if it is a flood field and the seeds are planted deeply with a digging stick that exposes less soil to drying and erosion. Excellent weed control also reduces demand for soil moisture.

The location variable needs to be fine-tuned to be more meaningful. Location should reflect specific variation in environmental and cultural characteristics. Did North Oraibi fields receive more moisture in 1994 or did more conservative farming practices account for higher yields here? Moisture data were not available for each field. This information conceivably could account for a great deal of yield variation.

One would expect that farmers with smaller fields would have more opportunity to nurture their fields. Field size needs to be broken down into smaller units precisely measured. There is a big difference between a field that is one-half acre in size and one that is nearly 3 acres large, for example.

One would also expect some varieties to do better under different environmental and cultural conditions. Does white corn do better under low moisture conditions, for example. Varieties must be precisely identified and tracked in order to determine how each performs under field conditions.

The change in planting technology has been particularly influential in Hopi corn farming. With the corn planter planting can be accomplished by one or two individuals in less time. One could argue that this has had a negative impact on social relationships. Some would also argue that the corn planter interferes with the link between the farmer and the earth. A farmer who walks his field and plants with a stick that is essentially an extension of his arm may have a more vital connection to nature and the care of his seeds than the farmer driving a tractor.

In an effort to better compare these two technologies from a production viewpoint, I examined the data on topography, planting depth, the number of seeds planted per hill, and yield. The two technologies did not vary greatly with respect to average planting depth and the average number of seeds planted. Farmers using the digging stick reported planting an average of 9" deep, while farmers with the corn planter averaged 8". The average number of seeds planted was 10" with the corn planter and 11" with the digging stick.

The most dramatic difference occurs with the relationship between topography, technology, and yield. Yield averages were

TABLE 10. A COMPARISON BETWEEN THE CORN PLANTER AND DIGGING STICK

	CORN PLANTER (17 fields)	DIGGING STICK (14 fields)
Average Planting Depth	8"	9"
Average Number Seeds/Hill	10	11
Average Yield--Open Field	125 lbs./ac. (12 fields)	137 lbs./ac. (8 fields)
Average Yield--Flood Field	121 lbs./ac. (5 fields)	352 lbs./ac. (6 fields)

comparable when the corn planter was used in open fields (125 lbs./ac) and flood fields (121.4 lbs./ac). A slight increase occurred when planting with the digging stick in open fields (137 lbs./ac.), but a huge increase was recorded for flood fields planted with a digging stick (352 lbs./ac.). Corn planted with a digging stick in a flood field yielded 157% more than corn planted in an open field with a digging stick and 182% more than corn planted in an open field with a corn planter. (Please note that these figures are drawn from a very small sample.)

These results introduce the importance of considering the relationships of all parts of the farming system. Did farmers planting with a digging stick in flood fields experience better yields because they are more knowledgeable farmers? Were yields higher here because the fields were relatively new or because the soil had recently been replenished by flooding? What role did precipitation play in explaining yield differences? Questions such as these need to be answered to fully understand production differences.

The results of this yield study convincingly illustrate one reason why Hopi farmers have farmed the way they have for generations: the yields are higher. In 1994, on the average, lower yields occurred where farmers deviated from traditional practices. These results merit consideration by farmers contemplating change with their corn farming program.

FARMER NEEDS/SUGGESTIONS

The interview concluded by asking farmers if they had any needs or suggestions for work or research with farming. The complete list of responses is given in Table 10. The majority of perceived needs relate to pest control.

TABLE 11. FARMER PROBLEMS/PERCEIVED NEEDS

PROBLEMS/SUGGESTIONS	NUMBER RESPONDING
Crows	10
Prairie dogs	4
Repair diversion dams/dikes	5
Worms	3
Kangaroo rats	3
Birds	2
Sources of technical information	2
Soil testing	2
Field leveling	2
Dogs	1
Lizards	1
Squirrels	1
Gophers	1
Porcupines	1
Information on pest cycles	1
Problem weeds	1
Pipes to develop irrigation	1
Youth not farming	1
Need formal education through the schools	1
Establish a seed bank	1
Establish an information bank	1
Establish an agricultural fair	1

Encourage gardening	1
Need source of Hopi sweet corn	1
Cooperative arrangements with farm equipment good	1
Need information on drip irrigation	1
Develop water potential near my field	1
People not paying for custom work	1
Need to start selling corn	1
Theft by Navajos	1
More Tribal investment in watershed management	1

RECOMMENDATIONS FOR FUTURE RESEARCH

This introduction to Hopi corn production amply illustrates the need for ethnographic research on the entire annual cycle of agricultural practices. Hopi knowledge and practices for all parts of the system need to be carefully documented. This is essential for obtaining complete and accurate yield data and for understanding exactly what farmers do and why. This research will also enable a better perspective of the research needs for current farming problems.

Let me illustrate with some concrete examples. Site selection has been considered a critical feature explaining the success of Hopi corn farming through time. Site selection has changed quite dramatically over the past decade with the appearance of "modern" or open fields. How and why has this change occurred? What are the cultural and environmental consequences of this change? Are modern fields less likely to be clan held? Are they more attractive with modern equipment? Will yields be consistently reduced here? Are traditional Hopi water and soil conservation techniques still operative? Are the knowledge and skills necessary to practice conservation techniques being preserved and transmitted to the next generation? How are these techniques being adapted to meet changes in farming?

A better understanding of yield variability requires more research on farming practices and moisture availability. With regard to seeding rates, for example, how do these rates relate to germination and planting technology? When is thinning done and what are the different methods used? How do these methods relate to yields? With regard to harvesting, what yield is removed with the green corn harvest? What kind of harvest do farmers get with their early corn? Efforts should also be made to measure rainfall and soil moisture content for each field. As mentioned earlier, yield data must be gathered for a number of years in order to take into account weather fluctuations.

The following considerations may be worth pursuing to better support Hopi corn farming. Farmers know that worms are a problem, for example, but they may not have attempted to identify these worms. This may be partly due to a perception that worm damage is rather minimal and unavoidable. This research shows that worm damage is not minimal. The determination of satisfactory means of control requires that the worms first be identified. The fall worm pest is the corn earworm or Heliothis zea. Some farmers think this is the same worm that eats their seeds and seedlings in the spring, but it is not. Some farmers noted that the worms are more abundant in wet soils, others say they are more abundant in dry soils. Are farmers referring to the same worm population?

Once all corn pests have been identified, a literature search could be done to determine the current status of biological control measures. Field trials or farmer-based research could be set up on the Reservation to determine the effectiveness of these measures in Hopi.

Few farmers expressed an interest in breeding or talked in detail about the different varieties of corn found on the Reservation. Information on the growing season of the different varieties would seem to be desirable, especially for those planting early corn or those farmers that need to replant. Are some varieties more resistant to worms or drought? Do some varieties yield better? Field trials to better document the agronomic characteristics and performance of the different varieties could be very useful to farmers.

Farmers commented on the need to improve and plant more Hopi sweet corn and the desirability of establishing a seed bank. A seed bank could be established to promote the preservation of the various varieties of corn and all the other crops raised on the Reservation. It could also function to facilitate the dissemination of seeds among Hopi farmers.

Farmers expressed an interest in having their soils tested for nutrient content. This information can be helpful in making decisions about when to let a field lie fallow, the desirability of considering organic fertilizers, and it might direct farmers to explore the potential of establishing a crop rotation scheme for their fields.

Crop rotations are practiced because they can improve soil fertility and yield, and they can effectively reduce pest and weed infestations. Rotating corn with beans or another legume, for example, acts to fix additional nitrogen in the soil, and nitrogen is generally the limiting factor in corn production. Could dryland varieties of alfalfa be grown in Hopi? What fallow practices are recommended for each field type? And, would cover crops be suitable for fall planting?

Farmers cited a need for technical farming information, yet no one referred to a source already on the Reservation, the Cooperative Extension agent located in Kykotsmovi. Are there ways to facilitate an exchange of information between the community and Cooperative Extension?

A number of suggestions from farmers may be suitable for discussion at the Tribal level: the provision of equipment and labor to help farmers build and repair diversion dams and dikes; improved watershed management; the promotion of farming among the youth with a formal school curriculum for all classes; the establishment of cooperatives that buy and rent equipment at the villages; and discussions about the desirability of drip irrigation or the entry of Hopi farm crops into the marketplace.

The last two issues prompted farmers to remark on the importance of considering Hopi cultural traditions in agriculture and agricultural change. Change is part of life, and this is certainly the case with Hopi farming. The challenge is to direct or control change in order to make it work for the Hopi people.

NOTES

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1. These terms were collected from Leigh Jenkins and Walter Hamana of the Hopi Cultural Preservation Office.

2. Although some of these variety names were given by farmers during interviews, Leigh Jenkins and Walter Hamana provided this list of basic varieties.

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APPENDIX

NAME
ADDRESS

FIELD INVENTORY

LOCATION	# ACRES	PLANTED	SOIL CHARACTERISTICS

1.

2.

3.

4.

EQUIPMENT INVENTORY

1. TRACTOR

2. PLANTING EQUIPMENT

3. WEEDING EQUIPMENT

NAME AND DESCRIPTION OF VARIETIES PLANTED:

CRITERIA FOR SEED SELECTION

PREFERRED PLANTING TIMES

SEEDS/HILL
SEED DEPTH

WEEDING PRACTICES

IRRIGATION PRACTICES

PEST CONTROL PRACTICES

WATER/SOIL CONSERVATION PRACTICES

FERTILITY PRACTICES

CROP ROTATION SCHEME
YEARS IN CONTINUOUS CORN

PROBLEMS/NEEDS/RESEARCH SUGGESTIONS